STEP

Airless Vacuum Vapor Degreasing

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Utilizing

The Pollution Prevention Technology Application Analysis Template

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The U.S. Environmental Protection Agency - New England provided the Pollution Prevention Technology Application Analysis Template, a standard reporting format, and funding for this project.

This reporting format is also endorsed by the National Pollution Prevention Roundtable as a standard vehicle for technology transfer.

July 1999

DISCLAIMER

This document is designed to assist the user in analyzing the application of technologies. While it provides a template for the general types of questions that you should ask when evaluating a technology, it may not include all of the questions that are relevant to your business, or which your business is legally required to ask.

This document is intended to assist envirotechnology users, developers, and investors to make informed decisions about the commercial potential, process and environmental performance of specific products or prospective products under development. This document is not intended to communicate the full market scope or competitive position of any of the underlying technologies embodied by the product, but rather to illustrate the comparative effectiveness, or potential effectiveness, of that technology in the form of one or more specific products.

Preface

The Executive Office of Environmental Affairs' STrategic Envirotechnology Partnership (STEP) and the Toxic Use Reduction Institute (the Institute) located at the University of Massachusetts Lowell entered into an Interagency Service Agreement (ISA) to document the utility of the Environmental Protection Agency – New England's Pollution Prevention Application Analysis Template. The Institute enlisted the Gloucester, Massachusetts-based consulting company Greiner Environmental to complete an analysis of the Serec Airless Vacuum Vapor Degreasing Systems. Tim Greiner of Greiner Environmental is the primary author.

This analysis of the Serec Airless Vacuum Vapor Degreasing System is one of four analyses completed for this project. The other three reports are on the following technologies: Zero Discharge Technologies, Inc.'s Acid Recovery System; Suparator Thin Film Oil Recovery system; and M/A COM Inc's Semi-Aqueous Cleaning System. In addition, two narrative summaries discussing the practical utility of adopting the template approach for pollution prevention (P2) technology analysis have been prepared by Karen Thomas (formerly with the Institute) and Tim Greiner of Greiner Environmental.

The Institute would like to thank the Executive Office of Environmental Affairs and the Environmental Protection Agency – New England for their financial support of this project. The Institute acknowledges the generous cooperation of Anthony D'Amato of Zero Discharge Technologies Inc.

For additional information about any of these technologies or technology reports, please contact Paul Richard of STEP at 617-626-1042 or see the National Pollution Prevention Roundtable's web site at http://www.p2.org. For information about the P2 Technology Analysis Template, contact Abby Swaine of the Environmental Protection Agency – New England at 617-918-1841. For additional information on the Serec system, contact Serec Corporation at (401) 421-6080.

STrategic Envirotechnology Partnership

The STrategic Envirotechnology Partnership (STEP) is an innovative effort begun in 1994 to promote the growth of new environmental and energy efficient technologies in Massachusetts. STEP maximizes the existing resources of its partners, the Executive Office of Environmental Affairs and the University of Massachusetts system, to keep Massachusetts a leader in environmental business and to allow Massachusetts citizens to reap the positive benefits associated with the success of these new envirotechnologies.

STEP offers services in the areas of technology assessment, business support, applied research and development, technology demonstration, regulatory assistance and expedited permitting. For more information on the STEP program, contact Paul Richard at 617-626-1042.

Toxics Use Reduction Institute

Located at the University of Massachusetts Lowell, the Toxics Use Reduction Institute is a multi-disciplinary research, education and policy center. The Institute sponsors and conducts research, organizes education and training programs, and provides technical support to promote reduction in the use of toxic chemicals or the generation of toxic chemical byproducts in industry and commerce.

The Institute's Surface Cleaning Laboratory assists companies in matching specific cleaning needs with appropriate chemistry and process combinations. The Lab outlines cleaning options, tests actual parts or test coupons, evaluates commercially available cleaners, and helps define cleaning specifications.

For additional information about the Institute programs or the Surface Cleaning Laboratory services, contact the main number at 978-934-3275.

Introduction

The intent of the Environmental Protection Agency in developing and piloting the Pollution Prevention (P2) Technology Application Analysis Template (P2 Template) is to promote the use of technology application analyses as a method of promoting and accelerating the introduction and use of new pollution prevention technologies. The purpose of this technology application analysis is to assist potential users of P2 technologies in evaluating the applicability of innovative P2 technology to their needs. In addition, the template is designed to assist vendors of pollution prevention technologies in developing their own technology application analyses. This template is not intended to suggest that a vendor should limit the information provided to a potential user of a pollution prevention technology. Additional information beyond that suggested in this template, may be useful and should be made available.

This technology application analysis characterizes the main features of the Airless Vacuum Vapor Degreaser developed by Serec Corporation (also referred to as the *Serec System* or *Serec Process*), as well as its benefits, the costs associated with its implementation, regulatory aspects, and lessons learned from the application experience.

Serec's patented high vacuum, airless vacuum vapor degreasing technology utilizes organic solvents to clean metal parts. The process is compatible with a wide variety of substrates, solvents, and contaminants including:

- most metal and ceramic substrates; precision parts such as metal honey comb, polished bearing surfaces, silicone wafers, castings and PM parts, electronic connectors, and tubing.
- many organic solvents; most commonly PCE (tetrachloroethylene) and trichloroethylene
- contaminants such as oils, grease, wax, and particulate matter
- clean room applications
- custom applications

This technology application analysis covers airless degreasing at four shops with degreasing operations, each with a different combination of parts, contaminants and solvents. The system is suitable for a variety of combinations and Serec maintains a research, testing, and engineering lab for solving specific cleaning problems.

This template describes the technology in seven sections:

- Introduction
- Description of P2 Technology
- P2 Technology Application
- P2 Technology Performance
- Cost Information
- Regulatory / Safety Requirements
- Lessons Learned / Implementation Issues

Description of P2 Technology

Metal parts, at all stages of production from raw material to finished product, become contaminated by oils, greases, waxes, and particulate matter. In some cases, the contaminants serve a specific purpose, such as corrosion protection or lubrication for cutting and stamping tools, but in most cases, the contaminants must be removed. Traditionally, businesses used open-top vapor degreasing with organic solvents to clean their parts. Because of recent, more stringent regulations, open-top vapor degreasing has become less practical. Some manufacturers have switched to aqueous cleaners. While aqueous cleaners are more environmentally friendly, not all parts can be cleaned using aqueous systems. For example, aqueous systems can have a large footprint to accommodate handling, cleaning, and drying equipment. The high surface tension of aqueous based cleaners can inhibit cleaning effectiveness on parts with small openings and cavities. Long drying times and more stringent water discharge regulations are other limiting factors.

Serec developed its environmentally and work place friendly Airless Vacuum Vapor Degreasing system for firms unable to make the switch to aqueous cleaning. The system combines the cleaning effectiveness of solvent cleaners with the decreased environmental risk and relative safety of aqueous cleaners. The following section describes the Serec Process and Airless Vacuum Vapor Degreasing technology in greater detail.

Technology Description

Overview

Serec's patented high vacuum, airless vapor degreasing technology utilizes organic solvents to clean metal parts in a unique process. Though this process shares some commonality with traditional vapor degreasing systems, there is one major difference; the solvent is never mixed with air, so emissions are low.

The Serec philosophy is founded in *pollution prevention* rather than end-of-pipe pollution control. Traditional vapor degreasing takes place in open air. Since the presence of air neither enhances nor detracts from cleaning effectiveness, the air contamination which takes place during open-air degreasing is needless. By removing the air before introducing the cleaning solvent, the contamination problem is eliminated with no loss of cleaning effectiveness.

Serec's design represents significant improvements over early attempts at vacuum degreasing (i.e., high ratio). Early vacuum degreasers left a significant amount of atmospheric air in the vacuum chamber when solvent was introduced. This atmospheric air rises to the top of the vessel when the solvent is introduced, creating a stratified cleaning zone -- consisting of an air rich zone above a vapor rich zone. This stratification causes the cleaning of parts in the air rich zone to be slow and inefficient due to the slow diffusion of vapor through the air rich zone. Furthermore, air remaining in the closed chamber causes the pressure in the system to increase. Increased air pressure in the closed chamber means more heat and energy is required to vaporize the solvent and heat the parts at greater expense. The presence of air also causes problems during solvent recovery, because the air inhibits the condensation of the solvent vapor.

Serec's improvement over these early systems was to remove atmospheric air from the chamber down to less than 5 torr (1 torr = 1 mm Hg; 760 mm Hg = atmospheric pressure). For this innovation and for their system's process flexibility, engineering, and low emissions, Serec was granted U.S. Patent No. 5,240,507.

Detailed Description

During a typical cleaning cycle, the following processes take place: The chamber is loaded with parts to be cleaned. Once the door is closed and sealed, the air is evacuated from the degreasing chamber with a vacuum pump. A pressure of less than 5 torr is achieved.

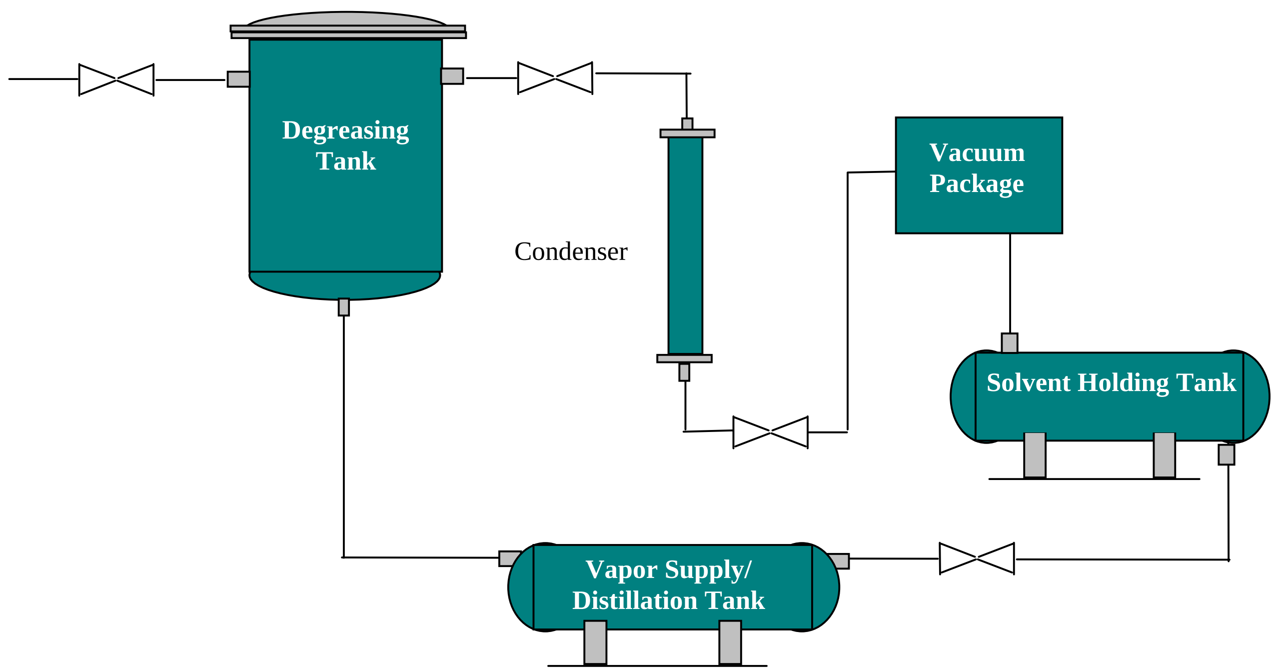
When the desired vacuum is achieved, heated solvent vapor is released from the vapor supply tank into the degreasing chamber. The warm solvent vapors then adhere as liquid to the cooler surfaces of the parts to be cleaned, producing the desired cleaning action. (This is the same process that takes place in an open-top vapor degreaser.)

During cleaning, condensation will heat the parts being cleaned. To cool the parts and to rinse deposits after cleaning, the parts are sprayed with liquid solvent. The cleaning and spraying cycle can be repeated for the number of times and duration initially selected by the operator. When the cleaning and spraying cycles are completed the vapor recovery process begins.

Both the vapor and liquid solvent are removed from the degreasing chamber during the vapor recovery process. The hot solvent vapor is moved from the degreasing chamber via a vacuum pump to a heat exchanger, where it is condensed. [See Diagram 1 below.] From the condenser, it is returned to the solvent holding tank. The liquid is drained from the bottom of the chamber to the vapor supply tank. As the pressure continues to decrease, the liquid solvent on the warm surfaces flash to a vapor and are removed via the vacuum pump. Since solvent cannot exist in the liquid state when the pressure of the chamber is reduced to below 5 torr, nearly all solvent is removed from the chamber by the vacuum pump prior to venting the system to atmosphere.

When the degreasing chamber is restored to atmospheric pressure, the air/solvent mixture is evacuated from the chamber through a carbon filter. With the chamber at atmospheric pressure again, the operator can open the door and remove clean, dry parts. The amount of solvent remaining in the chamber is well below OSHA short-term exposure limits. Since little solvent is released, there is virtually no solvent odor.

Diagram 1



The Serec system employs an Allen Bradley programmable logic controller (PLC) that permits users to customize up to eight menus. For example, cleaning cycles can employ one or a combination of vapor degreasing, soak (with or without ultrasonic), and spray steps in different sequences, duration, and temperatures. The PLC also includes various alarm points readable by the system operator -- such as vapor pressure, tank pressure, torr levels in working tanks, and temperature readings. PLC alarms alert the system operator if system set points are exceeded. A phone-line connection allows Serec technicians to read system parameters, either on site or from a remote location. While PLC menus are simple to read and make the technically sophisticated equipment simple to operate. Other key system attributes include:

- *Pumps*: Rotary piston and liquid ring pumps are standard on most Serec units. The liquid ring pump reduces system pressure from 760 torr (atmospheric pressure) to ~150 torr. The liquid ring pump pulls the system down to the operating pressure of ~1 torr. In some cases, a pneumatic diaphragm pump is used when the position of components does not allow for gravity feed of solvent from the degreasing tank to the vapor supply tank.

- *Solvent Storage*: The solvent storage tank is kept at ambient temperature. The vapor supply tank is maintained at operating temperature (e.g., ~140 for normal propyl bromide or 160-170 for trichloroethylene).

- *Distillation*: The distillation column is a jacketed pressure vessel. At low system pressure, the solvent boils at a low temperature. Vapors are condensed in the distillation column and a sump at the bottom of the column pumps the contaminants to a waste storage vessel. Waste from the system contains roughly 5 % solvent -- whereas conventional open-top vapor degreaser distillation waste contains ~30 % solvent.

- *Cooling*: Cooling capacity in needed to cool solvent to the liquid form for spraying and to keep the solvent storage tank at ambient (for efficient pumping). Serec specifics water cooing requirements (flow and temperature). The customer can use existing on-site chillers or evaporative cooling systems or, if necessary, purchase such systems from Serec or another vendor.

- *Heating*: Plant steam is normally used to vaporize solvent in Serec systems. Serec systems require steam between 15-50 psi. If the firm cannot meet the specification, it can purchase a boiler through Serec or from a vendor of their choice.

- *Air*: Air is needed to operate cylinder for door lifts, actuators for valves, and pneumatic pumps. Typical requirements are 100 cfm at 100 psi.

- *Electrical:* Electrical requirements for Serec systems are 480 V, 3 phase, 60 hertz service. Amperage ranges from 20 to 200 amps and depends on factors such as whether the unit includes an electrical boiler, chiller, pump size, size of degreasing vessel.

Serec systems are sized by capacity in pounds of parts degreased per hour (for steel) and by degreasing chamber dimension. Serec system specifications are outlined in the table below. Specifications may vary to accommodate customer needs. For example, customized long degreasing chambers (20 ft.) have built for firms degreasing long metal tubes.

Model	2000	2400	3600	4800
Capacity (lbs/hr)	80-400	200-800	600-2,000	1,000-4,000
Chamber - DxH (in.)	20x20	24x24	36x36	48x36
Dimensions - LxWxH (in.)		134x90x90	148x102x90	148x102x90

Technology Applicability

This section describes the applicability of this technology to users, the development history, and the advantages and limitations claimed by the technology vendor.

Applicability to Industry/User

Serec's airless vacuum vapor degreasing technology utilizes organic solvents to clean metal parts. The process is compatible with most metal and ceramic substrates including precision parts such as metal honey comb, polished bearing surfaces, silicone wafers, castings and PM parts, electronic connectors, and tubing. Serec has sold systems to the electronic connector, aerospace, honeycomb manufacturing,

medical, and capacitor manufacturing industries. The process is compatible with many organic solvents -- including PCE (tetrachloroethylene), trichloroethylene, hydro fluoro ethane, normal propyl bromide, hexane, various alcohols, etc. -- and a variety of contaminants such as oils, grease, wax, and particulate matter. The technology can also be used in clean rooms and for custom applications.
This technology application analysis covers airless degreasing at four shops with degreasing operations, each with a different combination of parts, contaminants, and solvents. (See Development/Application History below.) The system is suitable for a variety of combinations and Serec maintains a research, testing, and engineering lab for solving specific cleaning problems.

Development / Application History

Serec developed its airless vacuum degreasing technology in-house in response to the firm's need to reduce hazardous air pollutant emissions from its open top vapor degreaser (OTVD). In 1989-90, the State of Rhode Island threatened to shut down Serec's OTVD unless the company made significant modifications to the unit to bring it into compliance. Serec looked at alternatives, including aqueous cleaning. But since water was the biggest impurity in the firm's vacuum casting process, making aqueous cleaning work proved too difficult. One alternative Serec considered was separating air from the process at the beginning -- such an approach would be easier than separating solvent and air following the degreasing process. Applying vacuum processing principles the company was familiar with, Serec developed an airless degreasing system. Based on its in-house success, Serec decided to manufacture units for resale. The first units were shipped in 1992. As of July, 1999, Serec has sold roughly 55 airless vapor degreasing systems to firms in a variety of industries.

Lessons Learned During P2 Technology Development

Many advantages of the system were realized during development and subsequent commercial applications:

- dramatically decreased solvent use and improved solvent recovery solvent
- 97 to 99 percent reduction in degreaser air emissions
- dramatic reductions in worker exposure to airborne solvents and emissions
- elimination of NESHAP reporting
- BACT and LAER compliant

Based on Serec's experience, lessons learned include issues related to water contamination and contaminant carry over to solvent supply tank.

Water Contamination:
Water contamination of the solvent can be prevented by using a desiccant. Also Serec is working with solvent manufacturers to develop a test kit which will determine the acidity of the solvent and make recommendations for replenishing the acid inhibitor (an ingredient in many solvents).

Contaminant Carry Over to Solvent Supply Tank:
Contaminants with low boiling points (around the same temperature as the solvents) can cause problems during distillation because the contaminants can be carried over into the recovered solvent. This problem is often addressed by switching to a solvent of a lower boiling point or switching to greases, oils, and lubricants of higher boiling points. [Detailed information on the nature of the contaminants may be necessary for determining the difference in the vapor pressure and boiling point of the solvent and contaminant. Knowing solvent and contaminant characteristics allows Serec to choose a solvent, that when distilled, will not carry the contaminants into the supply tank.]

P2 Technology Application

The following section describes the use of the P2 technology at four application sites -- Electro-Spec, A.T. Wall, Texas Instruments, and Poclain Hydraulics. General information on each of these sites is presented in the table below.

Year	Location	Scale; Parts Cleaned	Results
1996	Electro-Spec, Inc.	Commercial; Coaxial Connectors	Degreaser solvent consumption reduced to 1.5 lbs per day
1996	A.T. Wall	Commercial; wave guide tubes	97% reduction in solvent consumption, 75% reduction in hazardous waste
Jan 1998, Dec 1998	Texas Instruments	Commercial; Loose Bi-metal discs, loose metal parts	Two units combined emissions is less than 20 gallons per year (~200 lbs) of solvent.
1999	Poclain Hydraulics	Commercial; Hydraulic motor components	No solvent added during first six months after installation.

P2 Technology Application

General Setting

Electro-Spec Incorporated, Franklin, IN

Electro Spec is primarily a plating shop which serves the electronic connector industry. However, part of the company's services is also to provide metal cleaning and degreasing for the electronic connectors. Electro-Spec's clients include the automobile, aerospace, military, electronics, and electromechanical industries. Electro-Spec works with many metals including molybdenum, beryllium, and titanium.

The contaminants typically found on the connectors are cutting oils. Electro Spec uses perchloroethylene to remove these cutting oils. Prior to installing the Serec airless vacuum vapor degreaser, the company's consumed 8,000 pounds per year of solvent. Electro Spec purchased a model HV2400 with a cleaning capacity of 6.7 cubic feet. The degreaser is used for simple degreasing and has a rotation unit for tumbling while degreasing. After the installation of this system the company decreased its usage to 1.5 pounds per day (approximately 375 pounds per year).

A.T. Wall, Warwick, RI

A. T. Wall manufactures a variety of products including wave guide tubes that are used to carry or transmit microwave radiation. The dimensions of the tubing must meet exacting specifications. During forming, the tubing is drawn through a series of dies with a special lubricants under high pressure. The force and friction of the drawing process produces heat which sometimes carbonizes the lubricant on the interior of the tubes. The cleaning and drying of the inside of the tubes is critical to their performance, because any contamination can change the length and cycle of the radio wave energy, resulting in inaccuracy or system failure.

Open-top vapor degreasers had been used to clean the tubes in the past, but because of new stringent air emissions regulations, A.T. Wall was forced to move away from the old degreasing methods. The company first investigated aqueous cleaning, but these systems were too large because of the additional cleaning, drying, and handling equipment. In addition, the aqueous cleaners were ineffective with longer lengths of tubing. Discharge of additional process water would be a liability as well. Some of the aqueous cleaners could also cause oxidation on tubing manufactured from alloys such as certain metal alloys present in the tubing.

The company also investigated aliphatic hydrocarbon solvents. The solvents performed well, but the low flash points of the solvents would require fire suppression systems. The solvents were slow to dry, causing throughput problems. Also, the odor of the solvents was disagreeable to many employees.

During their search for a cleaning process, the company contacted Serec Corporation. The Serec degreaser's design made it possible to clean and dry the exterior and interior surfaces of even the 20 foot wave guide tubing. In 1995, with the open-top vapor degreaser the company emitted 43,591 pounds of 1,1,1 trichloroethane at an expense of over $80,000. With the new Serec system, the company is able to clean with perchloroethylene, a less harmful solvent, and has reduced their solvent usage to just 3% of what was used previously, while reducing hazardous waste by 75%. The company has virtually eliminated fugitive emissions.

Texas Instruments, Attleboro, MA

Texas Instruments is a large manufacturer of electronic devices and electronic components. Each of two departments at the Attleboro plant that perform cleaning and degreasing operations purchased a Serec airless degreaser. These two departments perform cleaning functions for various other departments within the company, and consequently, the vacuum degreasers are used to clean many different parts including bi-metal discs and loose metal parts. (One of the few parts not cleaned by the Serec degreaser is printed circuit boards, although the two companies are currently running trials.) The discs are contaminated with mineral oil and the metal parts are contaminated with mineral, stamping, and rolling oils.

A model HV1800 of 2.7 cubic feet is used with trichloroethylene to remove the mineral oils from the bi-metal discs, and a model HV3600 of 14.1 cubic feet with perchloroethylene removes the mineral, stamping, and rolling oils from the various loose metal parts.

The permit limits for the previous cross-rod vapor degreasers (with covers) was 100 gallons per month facility-wide. With the new Serec systems, the combined usage is approximately twenty gallons per year or less.

Poclain Hydraulics

Poclain Hydraulics, an international firm based in France, recently opened a plant in Sturtevant, Wisconsin. Poclain Hydraulics manufactures hydraulic motors and pumps for the automotive industry and a variety of other applications. Many components of their hydraulic motors are contaminated with lapping slurry and require degreasing and cleaning.

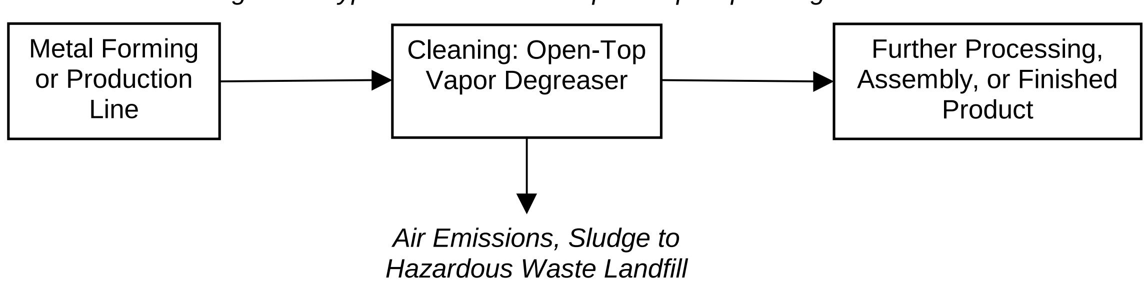
Poclain Hydraulics had been using aqueous cleaning, but required more effective cleaning because of the complex geometries of some of the components. Poclain kept their aqueous cleaning capability but added a Serec vacuum degreaser model HV283439HD of 20.9 cubic feet capacity in early 1999. The in-line batch system cleans parts prior to plasma pulse ion nitriding. Parts must be extremely clean of oils and residues -- for example, after solvent cleaning, operators must where lab gloves when handling parts. Poclain's system employs three spray and soak cycles (i.e., parts are sprayed, soaked, sprayed, soaked, sprayed, and soaked.) Poclain's permit limit prior to installation of the Serec system was 500 pounds per month. During the first seven months after the installation of the Serec system, the company has not added any solvent to the unit.

Technology Implementation At Industry Plant Site

General:

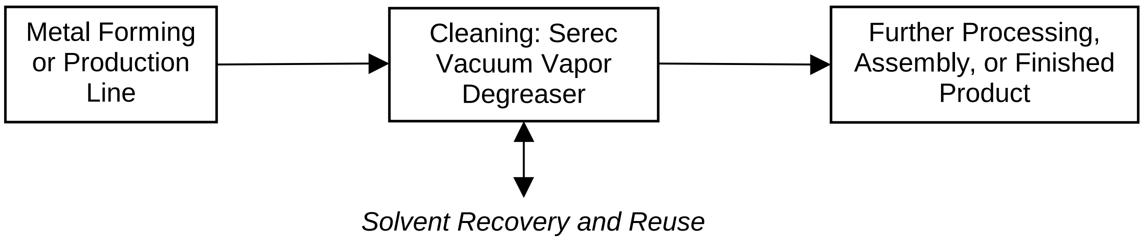
The Serec airless vacuum vapor degreaser can be "dropped-in" in place of an open top vapor degreaser. For example, a plant with an open top vapor degreaser typically would operate in the following manner:

Figure 1: Typical Process with Open-Top Vapor Degreaser



The process line after the Serec degreaser replacement would operate very similarly:

Figure 2: Typical Process with Serec Vacuum Vapor Degreaser



One difference not shown in Figures 1 and 2 is that the Serec vacuum vapor degreaser can be located more centrally in the plant than an open-top vapor degreaser, which means the flow of parts can be more logical and efficient. An open-top vapor degreaser is affected by winds and air disturbances causing emissions, odors, and worker exposure; therefore, the open-top vapor degreaser is typically located in an out-of-the-way area so that there is less disturbance and exposure. Consequently, parts to be cleaned are re-routed through the degreaser which can cause inefficiencies. The Serec degreaser however is not affected by winds and eliminates air emissions and worker exposure. Serec vacuum vapor degreasers can be located more centrally to process lines, making the flow of parts much more efficient.

The Serec airless system typically has only a fraction of the working volume of an open-top vapor degreaser. For example, at A.T. Wall the vacuum degreaser has one tenth the working volume of the old degreaser and yet it maintains the same throughput. The Serec system is able to maintain this throughput because the closed system allows rapid heating, and the vacuum lowers boiling points of solvents. (Rapid heating of solvent with an open-top degreaser would cause large solvent emissions.) Another method Serec uses to keep throughput at OTVD-speeds is to install two cleaning chambers that work in series but use the same pumps, holding tank, and distillation vessel. While an operator is unloading and reloading parts for one chamber, a second chamber can be degreasing parts.

P2 Technology Performance

This section presents performance data for the P2 technology as a result of actual applications. The technology's performance in the selected application is described by summarizing the application runs made and the performance achieved.

P2 Performance Criteria

The Serec airless vacuum vapor degreasing performance criteria include:

- percent reduction in solvent use, air emissions, and hazardous waste generation compared to a traditional open top vapor degreaser;
- dramatic decrease in in-plant fugitive air emissions and worker exposure;

P2 Technology Application Results

Electro Spec:

In 1996, Electro-Spec purchased a model HV2400 vacuum vapor degreaser. After installation, Electro Spec realized a ~95% reduction in solvent use.

Performance Serec Vacuum Vapor Degreaser			
Parameter	**Prior Solvent Use (with open-top degreaser)**	**Current Solvent Use (with Serec degreaser)**	**% Reduction**
Perchloroethylene	8,000 lbs/year	400 lbs/year	95%

The system enabled Electro-Spec to maximize throughput and minimize emissions while maintaining a high standard of cleanliness. The systems also allowed for savings in solvent purchases, waste disposal, and operating costs.

A. T. Wall:

A. T. Wall's initial goal was to significantly reduce the use and emissions of solvent for compliance reasons while maintaining cleanliness and customer satisfaction. Serec's vacuum vapor degreaser enabled them to accomplish this goal. A custom model Serec vacuum vapor degreaser was installed at A.T. Wall for use on wave guide tubes. The following results were achieved:

Performance of Serec vacuum vapor degreaser			
Parameter	**Prior Solvent Use (with open-top degreaser)**	**Current Solvent Use (with Serec degreaser)**	**% Reduction**
1,1,1 Trichloroethane	37,000	-	97%
Perchloroethylene	-	300	

A.T. Wall has also realized a 75% reduction in hazardous waste with no fugitive emissions. Disposal costs have been reduced from $7500 to $4000 per year. The value of the recovered solvent is about $11,000 per year.

Texas Instruments:

Texas Instruments' main interests in working with Serec vacuum degreasers were to increase throughput and cleanliness while also meeting more stringent permit limits. To accomplish this, two vacuum degreasers were installed at the Attleboro plant to replace cross-rod degreasers. Various metal parts are cleaned in the degreasers, and the following results were achieved:

Performance of Serec vacuum vapor degreasers				
Unit No.	**Parameter**	**1997 solvent amount with cross-rod degreaser (lbs/yr.)**	**1998 solvent amount with Serec degreaser (lbs/yr.)**	**% Reduction**
Unit #1	Use	63,775	2,155	96.6%
Unit #2	Use	23,915	3,984	83.3%
Unit #1	Hazardous Waste	30,297	2,112	93.0%
Unit #2	Hazardous Waste	19,332	3,966	79.5%
Unit #1	Air Emissions	33,478	42	99.9%
Unit #2	Air Emissions	4,582	17	99.6%

One of the contaminants in the process line that was being removed by one of the vacuum vapor degreasers was very fine particulate matter. Serec was able to custom design a filter for Texas Instruments which was able to remove the particulate matter from the recovered solvent.

Poclain Hydraulics:
Poclain Hydraulics goal in investigating Serec's vacuum vapor degreasing was primarily improved cleaning capability. The company had been using aqueous cleaning, but needed additional cleaning for its geometrically-complex hydraulic motor and pump parts. Another factor in Poclain's choice of vacuum degreasing was to use the best technology available in all aspects of the new plant. This would assure that technologies were compatible and prevent bottlenecks. Since the firm was pursuing ISO14000 certification, the Serec unit fit with the firms environmental performance goals.

Because Poclain had not previously been using solvents for cleaning, prior and current usage numbers and percent reduction numbers are not available. The firm estimates that annual emissions will be 15 lbs. Annual perchloroethylene is estimated to be 296 lbs. No solvent has been added since the unit's installation in January 1999, despite the fact that the degreaser has been operating three hours per day, five days per week.

Performance Compared to Existing/Traditional Technology

The data presented in the tables in the preceding section compare the Serec airless system with the open top vapor degreasers they replaced. One of the applications sites -- Texas Instruments of Attleboro, MA -- compiled a report comparing the Serec system with aqueous washer, conventional open-top vapor degreaser, and an upgraded MACT-compliant conventional OTVD. Note that this analysis was based on a five year cash flow projection and is specific to the Texas Instrument site. The analysis shows that the Serec system is the most cost effective option compared to aqueous washing and an upgraded MACT-compliance OTVD.

Attribute	Units	Conventional OTVD	Aqueous Washing	MACT-Compliant OTVD	Airless System (Serec)
Weight of parts cleaned	Kg/hr	200	180	195	365
Annual solvent use	lbs	22,000	na	21,000	6,200
Annual solvent emission	lbs	10,000	na	3,000	5
Annual solvent recycled	lbs	10,000	na	16,000	6,000
Annual solvent disposed	lbs	2,000		2,000	195
Annual Detergent Use	lbs	na	6,500	na	na
Annual VOC Emissions	lbs	na	650	na	na
Annual Water Use	gal	na	500,000	na	na
Energy Rating	-	1.00	1.10	1.25	0.95
Overall Cost Rating	-	1.00	1.20	1.42	1.05

Cost Information

This section will present cost information associated with the design, construction, startup, and operation of the P2 technology. This discussion should provide the name of the company supplying the information presented and the costs estimated in current US dollars.

Capital Costs

Serec, Inc. has four standard models and currently uses the following cost estimates for their technology. These costs as well as the specific costs for models purchased by the application sites are listed in the tables below.

Model	Capacity (lbs/hr steel)	Approximate Cost*
2000	80-400	$40,000
2400	200-800	$90,000
3600	600-2,000	$185,000
4800	1,000-4,000	$225,000

*Final cost of the unit is a function of pump size, throughput, storage tank size, and custom components.

Location	Unit	Cost
Electro-Spec, Inc.	HV2400	$ 91,000
A.T. Wall	custom model with 20 ft long degreasing chamber	~$ 300,000
Texas Instruments	HV1800 (2.7 cu. ft.) HV3600 (14.1 cu.ft.)	$ 130,579 $ 186,622
Poclain Hydraulics	20.9 cubic foot custom model	$ 237,607

Operating Costs

General:
Operating costs for the Serec system tend to be lower than with traditional open-top vapor degreasers. Most of the savings in operating costs afforded by the Serec system are a result of decreased solvent usage. The Serec system recovers and reuses solvents resulting in :

- decreased solvent purchase costs
- decreased waste disposal costs
- decreased energy costs
- decreased regulatory reporting costs

Another area of savings made possible by the Serec system is operator labor costs. The Serec degreaser incorporates an Allen Bradley PLC which allows the degreaser to be programmed, thereby reducing operator interaction and labor costs associated with cleaning operations.

Each of the application sites reviewed in this report were contacted and asked to supply cost operating cost information. Electro Spec was unable to supply detailed information. Detailed data was gathered from A.T. Wall and Texas Instruments. The two firms collected and analyzed slightly different pieces of information and are not directly comparable -- however both firms show significant operating cost savings associated with the airless system.

A.T. Wall:
A.T. Wall estimates its yearly operating costs decreased from ~$140,000 for the open-top vapor degreaser to ~$40,000 for the vacuum degreaser (see table below).

Annual Cost	OTVD	Serec System

Category		
Misc.	3,000	500
reporting	9,000	0
utility	1,000	2,500
labor	40,000	31,000
solvent waste	7,500	4,000
oil waste	2,000	
solvent cost	78,000	2,340
TOTAL	$ 140,500	$ 40,340

Texas Instruments:
Texas Instruments compiled cost savings information for two systems. These cost savings are presented below in the form of reoccurring annual savings.

Cost Category	Cost Savings ($)
Annual Energy Cost Saving	12,000
Annual Chemical Cost Savings	61,500
Annual Waste Disposal Cost Savings	8,000
Annual Avoided Compliance Costs	16,000
Estimated Avoided Permitting Costs*	14,000

*one time avoidance

TI also noted that the Serec system has not had any spills, leaks or other upsets that require emergency response. TI found that itself responding to such minor incidents on OTVDs on a frequent basis, with equipment downtime estimated at roughly 30-40 hours annually.

Poclain Hydraulics:
Since Poclain installed the Serec unit in a new process line, information comparing the system's performance to an OTVD were not available. The firm does however keep track of system operating costs. Their unit costs roughly $37-39 per hour to operate -- roughly $9,500 annually. This cost include utilities for chillers, gas for the steam boiler, spare parts, etc. The cost does not include labor costs (maintenance or operation).

Cost Benchmarks

Very little information was available on Serec system return on investment.

Electro Spec
- Solvent Purchase Savings = $5300
- Elimination of disposal costs = n/a
- Payback period = n/a
- Return on investment = n/a

A.T. Wall
- Solvent Purchase Savings = $75,000
- Elimination of disposal costs = $3,500
- Payback period = 4 years
- Return on investment = n/a

Texas Instruments:
- Solvent Purchase Savings = $61,500 (for two systems)
- Elimination of disposal costs = $8,000 (for two systems)
- Payback period = for HV3600 -- payback of 3.2 years
- Return on investment = n/a

Poclain Hydraulics:

- Purchase savings and elimination of disposal costs information is unavailable because the facility had not previously been using solvents.
- Because the facility was only recently opened, no estimates are available for payback period and return on investment.

Regulatory/Safety Requirements

This section reviews information regarding the regulatory requirements related to the implementation of the Serec system

Applicable Regulations and Permit Requirements

Compared to an open-top vapor degreaser, there are relatively few regulations and permit requirements associated with the Serec airless degreaser. In most cases, state and municipal regulatory authorities handle most permitting activities. The list below contains regulations applicable to the Serec system, the corresponding regulatory authority, and a brief description of how the regulations apply.

Regulation	Authority	Applicability
Clean Air Act	US EPA, state, and/or local	Serec systems have low air emissions and are below the permitting thresholds in many states.
Occupational Safety and Health Administration	US Dept. of Labor, state	workplace emissions must meet chemical-specific exposure limits
Resource Conservation and Recovery Act	US EPA, state	most systems generate hazardous waste which must be managed and disposed of accordingly.

Because there are virtually no emissions from the degreaser, the system exceeds Occupational Safety and Health short term exposure limits. Emissions from the degreaser are well below thresholds established by the Clean Air Act Amendments of 1990 for hazardous air pollutants (Subpart T NESHAP requirements for Halogenated Solvent Cleaners). The Serec system has been certified as Best Achievable Control Technology (BACT) and Lowest Achievable Control Technology (LAER) compliant by the California South Coast Air Quality Management District[1].

Some state air regulations may apply however. For example, in the Commonwealth of Massachusetts, any degreasing unit that emits hazardous air pollutants must file a one-time “source registration” with the state regulatory agency. The registration is not a permit however and is merely a means to notify the agency that the firm has a source that hazardous air pollutants. Because states and many local areas have different requirements, prospective purchasers should consult state and local authorities prior to installing any cleaning process.

Since most Serec systems generate hazardous waste still bottoms that are RCRA regulated, firms must manage their wastes accordingly. Waste management requirements include hazardous waste identification of the waste, generator registration with the US EPA, use of a licensed hazardous waste transporter, and compliance with requirements for waste storage, handling and worker training.

The table below compares the regulatory applicability and permit requirements of the Serec system with standard open-top vapor degreasers.

[1] US EPA defines two BACT tiers for the batch vapor degreaser source category. First is the use of an automatically operated airtight or airless cleaning system that emits no more than [$4.3 \times V^{0.6}$] lb/mo. of VOCs, where V is the cleaning chamber volume in cubic feet. Use of alternative equipment is allowed provided such equipment is subject to the same emissions limitation (lb/month of VOCs) as calculated above. If it is technically infeasible to use Tier 1 equipment because of part deformation, or inherent partial pressure, or other technical infeasibility, then sources must use equipment that does not exceed [22 x A] lb/month of VOCs, where A is the solvent surface area in square feet.

Regulation	OTVD applicability	Serec Applicability
Exempt from CAA Subpart T NESHAP for degreasers	no	yes
Clean Air Act LAER compliant	no	yes
BACT Compliant	may require modifications	yes
RCRA Hazardous Waste Management Requirements	yes	yes
State/local air permitting requirements	check w/ state/local agency	check w/ state/local agency

Health/Safety Issues

Two main health concerns in cleaning processes are worker exposure to solvents and flammability. Serec's airless degreaser design takes both of these health concerns into account. By virtually eliminating emissions from the degreaser, Serec has significantly reduced potential health risks to workers that could result from solvent exposure. Furthermore, unlike traditional open-top vapor degreasers where operators or maintenance personnel must frequently add solvent to the system to make up for evaporative losses, the Serec systems consume very little solvent --thereby reducing exposure and the risk of spills and accidents. At one application site, operators no longer have to pump 10 gallons to fill the OTVD sump each day. The Serec system has dramatically reduced the opportunity for site personnel tin come in contact with solvents.

In 1997, Serec performed air monitoring tests on of its units using EPA designated methods and calibration procedures. Tests were taken for tetrachloroethene at 8 locations The results are presented below.

Location	Result (ppm)	Location	Result (ppm)
Ambient Air	0.52	Front Side Tank Cover Open	0.46
Front Side Tank Cover Closed	0.65	:Left Side Tank Cover Open	0.66
:Left Side Tank Cover Closed	0.62	Inside Tank	0.55
Back Side Tank Cover Closed	0.62	Right Front Corner Tank Cover Closed	0.67

Texas Instruments took air samples around one of its Serec units. The TI specification for workplace levels of perchloroethylene around the unit was 20 ppm. The NIOSH time weighted average (8 hour workday) for perchloroethylene is 100 ppm. The NIOSH ceiling recommended exposure limit is 200 ppm and should not be exceeded at any time during a workday. Measurements inside the chamber before unloading was unable to detect any perchloroethylene. The equipment detection limit was 1 ppm.

Serec has addressed the issue of flammability in a similar way. First, Serec recommends the use of more stable solvents with higher flash points, such as perchloroethylene and trichloroethylene. Serec steers users away from solvents like alcohols, that are very flammable, when cleaning effectiveness can be accomplished by a less flammable solvent. Also by using a closed, airless system Serec significantly reduces the possibility of ignition. The Allen Bradley PLC that is incorporated into the degreaser also contains alarm points that notify the operator if the equipment is operating out of the set points.

Lessons Learned/Implementation Issues

This section reviews various lessons learned and system implementation issues. Information for this section was collected from application test sites as well as from the manufacturer.

Design Issues

System Throughput:
Like any piece of capital equipment, sizing the system to meet existing and future needs is extremely important. If the system is sized too small, the unit will be throughput limited. If the system is sized to large, the return on investment will suffer since the unit will be under utilized. One application site, Electro Spec, found its unit was too small to meet demand. The company examined the option of adding a second degreasing chamber to the unit -- a cost effective choice since the second chamber would use the units pumps, controls, condenser, etc., and would operate while the first chamber was being unloaded and reloaded. However, such a modification required taking the system off line for 2-3 weeks -- a requirement Electro Spec could meet. Electro Spec chose instead to purchase a second unit to meet its throughput needs. Poclain Hydraulics purchased a system to meet future demand -- the output from two 30 minute cycles is sufficient to supply firm's daily heat treating operation for an entire day.

Infrastructure -- Heating & Cooling:
Since the Serec system requires cooling capacity and heat to condense and vaporize solvent, the need for infrastructure modifications must be determined on a site-by-site basis. For example, Poclain Hydraulics had to purchase a chiller since they could not rely on the firm's existing evaporative cooling during hot summer months. Texas Instrument's system are hooked up to the firm's evaporative cooling system -- but TI found it necessary to supplement the evaporative cooling process during hot summer months when the cooling required to condense solvent for the spray wand took too much time and reduced system throughput.

In the case of plant steam energy, Poclain Hydraulics installed a separate small (10hp) boiler to provide steam to the unit. Initially, the boiler was unable to deliver sufficient steam to heating the solvent to the vapor state -- dramatically reducing throughput while the boiler worked to produce sufficient pressure. Firms are advised to properly engineer boiler needs to the system -- taking into account existing demand, and added demand from the Serec system.

Custom Design:
Many of the units Serec sells involve some type of custom design --typically to the degreasing chamber and for part loading/racking/baskets/rotation requirements. Serec has a staff of engineers and chemists that test-clean parts and work with companies to design an effective system. However, customized design did lead to problems at several application sites. At Texas Instruments, threaded bolts on a Ferris-wheel like rotation device broke off and had to be redesigned. At Poclain Hydraulics, a custom cleaning chamber door design has exhibited vacuum sealing problems. Despite these customization problems, all application sites highly endorsed the Serec system. Firms seeking custom design modifications should seek performance guarantees.

Implementation Considerations

Maintenance Compared to OTVDs:
All moving parts in the Serec degreaser (pumps, etc.) are surrounded by threaded connectors so that the parts can be replaced if necessary. A preventative maintenance (PM) schedule is supplied with all equipment. The PM schedule calls for periodic inspection and replacement activities at specified time intervals (e.g., weekly, monthly, and annually). PM activities include replacement of worn seals, resetting

the PLC program, tightening fittings, changing of vacuum pump oil, and particulate filter replacement. Application opinion of the maintenance required to the system compared to an open-top vapor degreaser varied.

According to Electro Spec, the system is “pretty user friendly”, requiring period vacuum pump old changes, inspection and replacement of o-rings on door seals. Electro Spec stated that the unit “met all our expectations of what they (Serec) promised.... coming from an open top vapor degreaser, the difference was night to day.” The firm’s old OTVD required a twice annual pump out and cleaning, and constant monitoring of solvent temperature and acid levels. Electro Spec estimates the airless system requires 1/3 the maintenance of the firm’s OTVDs.

Unlike Electro Spec, TI found that its airless system required *more* maintenance time that the OTVDs it replaced. TI’s OTVDs had nearly 100% up time and needed to be shut down only 1/yr. The firm estimates their OTVD required .5 hours per week of maintenance time while the Serec unit requires 1-2 hours per week. According to a TI engineer, the Serec unit has maintenance requirements comparable to “any other complex piece of equipment”. Poclain Hydraulics’ maintenance estimates mirrors that of TI’s. Maintenance of the system is greater that conventional the OTVD’s the firm was familiar with.

The difference results reported by the various application sites are difficult to interpret since the tasks one firm assigns to the maintenance department, another may assign to operators or environmental staff. For example, liquid level tracking, acid acceptance testing, NESHAP-required wind speed monitoring, and additions of solvent to a degreaser could be performed by any of the these organizations.

Vacuum Systems:
For firms that have not previously operated vacuum system, running and maintaining vacuum equipment requires training as well as a bit of trial error. Two application site had not had such prior experience and noted this issue -- although neither said learning to run and maintain vacuum systems was a significant impediment.

Labor:
Several application sites found labor savings as a result of the unit. Once the unit is loaded, the PLC manages the entire process, freeing up operator time that previously was devoted to lowering and raising the hoist, turn on and off spray wands and ultrasonic systems, etc. In applications were the systems are undersized, operators must quickly unload and reload parts to maintain throughput requirements.

Start-up and System Uptime:
Start-up was relatively straight forward at Poclain Hydraulics. The firm used company electricians and plumbers to install the system. A Serec Field Technician spent three days with Poclain representatives, going through the system, preventative maintenance methods, PLC programming, interpreting system error codes, etc. Poclain’s system, “ran pretty good right from the get go.”

Both Electro Spec and Poclain Hydraulic have experienced very little downtime due to mechanical failure. Poclain Hydraulics did have an issue with an undersized boiler that -- until it was resolved -- dramatically reduced system throughput. Two of the units purchased by Texas Instruments had start-up issues -- just the normal debugging that accompanies any new piece of equipment. TI did experience significant early downtime problems with two other systems. One unit’s distillation column was undersized and could not keep the solvent sufficiently free of contaminant. The second unit had mechanical problems with a custom designed rotating spindle. After correcting these problems, up-time has improved considerably with several units having gone over a year without a breakdown.

Over Cleaning:
TI found that the Serec system was over-cleaning some parts -- resulting in flash corrosion on the parts. TI modified the process to leave some oil residue on the parts to prevent the problem.

Limitations In Application

Serec states that there are no known limitations of the system in terms of cleaning traditional substrates (i.e., metal and ceramics). The applications that have proven to be the most challenging for Serec systems are precision cleaning related where a firm wants to remove insoluble particles from the parts. Removing such particles requires complicated soak, flushing, rotation, and ultrasonic action. Serec is currently working with several firms to engineer systems capable of precision cleaning particle removal.